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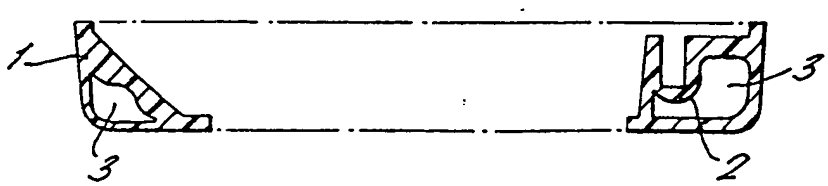
(54) Method of injection moulding and mouldings produced thereby.

(57) A resin moulding is produced by introducing molten synthetic thermoplastic resin (19) into a mould cavity (13), sufficient to fill completely the mould cavity. Subsequently, during the cooling of the resin, pressurised gas is introduced into the resin within the mould cavity. The resin moulding cools and hardens in the mould cavity whilst the gas is maintained under pressure. The mould cavity is designed to manufacture mouldings with unevenly distributed thick walled sections (3) connected to at least one gate (4;44) for the introduction of the pressurised gas, which flows only within the resin forming the thick walled sections and immediately adjacent areas of the moulding thereby taking up the shrinkage in the resin.

FIG. 3.



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METHOD OF INJECTION MOULDING AND MOULDINGS PRODUCED THEREBY

This invention relates to a method of injection moulding and mouldings produced th reby.

The manufacture of various types of synthetic resin mouldings is known using various suitable resin materials such as, for example, general purpose plastics, engineering plastics and thermoplastic resins and adopting appropriate moulding methods such as, for example, compression moulding, extrusion moulding and injection moulding. Due to the rapid penetration of electronic equipment e.g. facsimile terminals, word processors, small to medium size computers, and telecommunications terminals, there is an increasing demand for housings for this equipment made from synthetic resins. The advantages of housings made from synthetic resins are lighter weight and the possibility of one piece mouldings. There is also a strong demand for larger size housings to be made in the form of synthetic resin mouldings.

For such housings there is a requirement for a pleasing external appearance, with no appreciable inward bending, and a high moulding accuracy with no appreciable outward bending. There is a strong requirement for lighter housings. Furthermore, it is desirable that the housings or other mouldings do not require painting or other after treatments.

Various technologies for manufacturing mouldings which meet these various requirements have already been proposed. For example, in order to manufacture lighter mouldings, there exist well-known methods using synthetic resin materials in which a molten resin is mixed with a foaming agent and expanded mouldings are produced by injection moulding. It is, however, very difficult to manufacture thin walled mouldings using these methods, and the external appearance of such mouldings is poor. Various techniques have been proposed to compensate for this poor external surface appearance in which a hardened surface skin layer is formed and the inner section comprises an expanded layer. Other methods of manufacturing lighter mouldings are also known in which hollow internal layers are introduced into the mouldings. However, these methods are not appropriate for thin walled mouldings. Also, the moulding cycle is long and unsuitable for moulding the above-mentioned housings.

Methods have also been proposed for producing hollow mouldings in which the quantity of molten resin injected into the mould cavity is insufficient to fill the cavity and subsequently pressurised gas only or pressuris d gas and molten resin are injected to fill the mould cavity. However, with these methods there is a tendency for th gas to pierce through the molten plastics surface. The formation of the desired moulding is also hindered when gas only is injected under pressure and the injection of gas is not very carefully controlled. This lack of control renders these methods unsuitable for complex shaped mouldings.

A method has been proposed in which the operating conditions are controlled so that molten resin and gas flow simultaneously into the mould space and hollow mouldings are manufactured. However, even with this method gas will easily pierce the resin surface when, for example, resin materials are used which have a low viscosity in the molten state.

Ribs are frequently used as strengthening sections in order to allow a reduction in the wall thickness of mouldings having a large surface area and to provide strength and rigidity to the resulting thin walls. However, it is well known that inward bending of the surface occurs in the ribbed sections of such mouldings and the external appearance of these mouldings is poor.

According to the invention there is provided a method of producing resin mouldings comprising introducing molten synthetic thermoplastic resin into a mould cavity, introducing pressurised gas into the resin, and allowing the resin moulding to cool and harden in the mould cavity whilst maintaining the gas under pressure, the mould cavity being designed to manufacture mouldings with unevenly distributed thick walled sections connected to at least one gate for the introduction of the pressurised gas, wherein the mould cavity is completely filled with the resin, and subsequently the pressurised gas is introduced into the resin within the mould cavity during the cooling of the resin, the gas flowing only within the resin forming the thick walled sections and immediately adjacent areas of the moulding and thereby taking up the shrinkage in the resin.

Preferably the method includes maintaining the pressure of the gas within the gas filled sections during the cooling stage of the moulding cycle until the moulding can itself sustain the form dictated by the mould surface.

It is also preferred that the method includes venting the gas filled sections to the atmosphere before opening the mould.

The invention also provides a moulding produced by the method as defined above.

By way of example, specific embodiments in accordance with the invention will be described with reference to the accompanying drawings in which:-

Figure 1 shows an injection moulding machine for producing injection mouldings by a method in accordance with the invention;

Figure 2 is a plan view of an injection moulding produced employing a method in accordance with the invention;

Figure 3 is a section along line A-A in Figure 2;

Figure 4 is a section along line B-B in Figure 2;

Figure 5 is a section along line C-C in Figure 2;

Figure 6 is a section along line D-D in Figure 2; and

Figure 7 is a section along line E-E in Figure 2.

This example is concerned with the production of mouldings using moulds which are designed to provide rib and/or boss structures. Molten synthetic resin is injected into the mould cavity and allowed to cool. Thus mouldings are formed which contain ribs and/or bosses. When the above-mentioned mouldings are formed using conventional injection moulding, volumetric contraction of the resin occurs during the cooling stage of the process in which the resin inside the mould cavity hardens from the molten state. In particular inward bending of the surfaces of the mouldings occurs on the rib or boss sections. One method of trying to prevent this type of bending is to maintain a high molten resin injection pressure during moulding. However, this method of prevention is not satisfactory since, for example, cooling of the gate sections or thin walls near the gate sections occurs faster than in other areas, and thus the pressure effect does not adequately work on the desired sections. Conventional injection moulding also gives rise to outward bending of the moulding since even if the resin injection pressure is high around the gate, the pressure effect diminishes in relation to the distance from the gate, and this causes differences in volumetric contraction in proportion to differences in pressure effect.

The present invention provides a method of producing mouldings which possess the above-mentioned rib structure and, if required, variable thickness wall sections such as boss structures or verticle pin sections. A metal mould is used which is designed to distribute and connect the thick walled sections, which correspond to the desired ribs, to the desired location from the gate section. The mould has a mould cavity which is filled with resin by injecting molten synthetic resin into the mould cavity. The resin within the mould cavity immediately starts to cool and shrink. During the cooling and shrinkag of the r sin pressuris d gas is injected into the mould cavity from th gate section. The injected pressurised gas passes from the point of injection at the gate section only through th centre of the unevenly distributed thick walled sections and those areas immediately adjacent, which contain resin still in the molten state, and thus hollow sections are formed in the thick walled sections. The gas which fills the formed hollow sections is maintained under pressure, the mould itself cools and the resin is allowed to harden. The decrease in volume or shrinkage of the moulding which corresponds to the volumetric contraction during cooling of the molten resin is displaced by the further introduction of the pressurised gas, the pressure of which is maintained during the cooling of the molten resin, and thus the shape of the moulding is kept the same as the shape of the moulding cavity. When the resin has cooled sufficiently for the moulding to be capable of retaining the form dictated by the mould surface, the gas filled sections within the moulding are vented by evacuating the gas to the atmosphere. The mould is then opened and the moulding removed. By this method, the resulting moulding possesses an excellent external appearance which is an exact copy of the surface of the moulding cavity, and has minimal inward bending of the surfaces. Furthermore, since the passage of gas through the thick walled sections easily reaches the sections distant from the gate, without loss of pressure, the pressure effect of the gas reaches the whole of the moulding, and thus practically no outward bending due to the volumetric contraction of the resin, is visible on the resulting mouldings.

Compared with hitherto known methods in which an attempt to prevent outward bending is made by maintaining a high molten injection pressure, with the present invention it is not necessary to impose a high injection pressure on the moulding equipment which would exert unreasonable mechanical stress. Also, since this invention only requires a low mould clamp pressure and deformation caused by differences in volumetric contraction of the resin during cooling is controlled, the cooling time for the resin in the moulding cavity is reduced. Consequently this invention enjoys the advantage of a shorter moulding cycle time compared with conventional injection moulding cycle times. These advantages are extremely useful in practice.

There are no special restrictions on the thermoplastic resins which can be used with the method of the present invention. The method can be applied not only to general purpose plastics such as polyolefins, polystyrene, ABS resins, AS resins, PVC resins, methacrylic resins and fluorine based resins but also engineering plastics such as nylon, saturated polyester resins, polycarbonate resins, polyarylate r sins, polyacetal resins, polysulfones, and modified polyphenylene ether resins. Th method can also be applied to fibre strengthened

resins.

In the realisation of this invention, conditions such as the temp rature of the molten r sin during injection moulding, the injection pressure, and injection speed; the injection gas timing, quantity, pressure and speed; and the mould cooling time, will be selected and controlled in relation to the kind of resin being used and the shape of the mould cavity, and thus cannot be unconditionally specified.

Inert gases should be used for the injection gas, and the preferred gas is nitrogen.

For some mouldings it is convenient to introduce the gas through an outlet within the resin injection nozzle, for example, as described in British Patent No. 2139548. In other cases, the gas may be introduced at a separate position from the resin which is described in detail in British Patent Application No. 8805719.

Similarly, there are several known methods for performing the step of venting the gas filled sections within the moulding before opening the mould. For example, the gas filled sections may be opened to the atmosphere by withdrawing either the resin injection nozzle or the gas injection nozzle. Alternatively valve means may be provided at the point of gas entry or gate section which are closed during introduction of the gas and can be opened for venting the hollow sections. Again suitable valve means are described in detail in British Patent Application No. 8805710. A further known method described in British Patent Application No. 8722620 involves a vent pin insert in the mould which can be withdrawn to open the gas filled sections to the atmosphere. In some cases withdrawal of the pin may pull or fracture a piece of the moulding thereby creating an outlet through which the gas may pass to the atmosphere.

It will be appreciated that it is possible to obtain high precision mouldings with minimal inward bending of the unevenly distributed thick walls due to volumetric contraction, and minimal outward bending due to deformation. Also, as was mentioned above, it is possible with the present invention to reduce the moulding cycle time and to reduce the moulding costs compared to conventional injection moulding. Consequently, the method of the present invention is extremely appropriate for mouldings which require a large surface area and thin walled sections, in particular, for the moulding of housings. However, the invention is not restricted to the production of housings, but can be used for other synthetic resin mouldings which have boss structures or vertical pin structures.

Referring to the drawings, Figure 1 shows one example of apparatus which is described in detail in British Patent Application No. 8805719 and which can be employed to produce injection mouldings by the method of the invention. In that apparatus, a mould 9 of an injection moulding machine has upper and lower parts 11, 12 defining a mould cavity 13 of complex design and incorporating a rib 16. The mould parts 11, 12 are mounted between a fixed upp r platen 10 and a low r platen 14 movable by a hydraulic ram 15. Also, in this embodiment, within the upper mould part 11 is a hot runner manifold 17 leading to a desired point of entry or opening 43 to the mould cavity 13.

A screw ram 18 is provided for introducing molten thermoplastics resin 19 through a nozzle assembly 20 to the hot runner manifold 17 and hence through the opening 43 to fill the mould cavity 13. The nozzle assembly is provided with a shut-off slide valve 21 actuated by a bell-crank lever 22 and a link 23 connected to a hydraulic cylinder 24. The valve 21 is shown in its closed position at the end of that part of the moulding cycle which includes the introduction of the molten resin. The closed valve 21 prevents any return movement of the resin to the barrel of the screw ram 18. The screw ram may then be refilled with resin in preparation for the next moulding cycle.

The passageway through which pressurised gas is introduced to create a gas containing hollow 25 in the molten resin 19, as the resin cools and tends to shrink, is the bore 28 of a retractable nozzle or valve member 26 connected to the piston 29 of a hydraulic or pneumatic cylinder 27. The downstream end of the nozzle 26 is located at a separate opening 44 in the mould cavity and contains a non-return valve comprising a ball held captive by a screw-on cap. Pressurised gas is supplied to the upstream end of the nozzle 26 from a chamber 35 by a piston and cylinder 33, 34, the chamber 35 holding a measured amount of gas, e.g. nitrogen, which it is required to introduce into the molten resin. The chamber 35 is connected to the nozzle 26 via a solenoid operated valve 36, and to a gas supply (not shown) via a non-return valve 37 and a pressure regulator 38. Downstream of the valve 36, the connection has a feed to waste via another solenoid operated valve 39.

The piston and cylinder 29, 27 is controlled via a solenoid operated valve 40 by control means (not shown) to move the nozzle 26 between a forward position, as shown, and a withdrawn position. In the forward position, the nozzle 26 is in sealing engagement with a conical valve seat of a valve port 42 opening directly into the mould cavity at the opening 44 and provided, in this embodiment, by an insert 41 in the lower mould part 12. The pressure applied by the piston 29 is greater than the pressure applied by th molten resin within the mould cavity 13 and the back pressur of the gas which is creating the gas containing hollow 25. In the withdrawn or valve port open position of the

nozzle 26, gas pressure within the hollow is relieved through the opening 44, i.e. gas from the hollow readily passes through the valve port 42 into a second passageway 51 surrounding the nozzle 26 to the atmosphere. The non-return valve in the nozzle 26 prevents th gas returning back along the bore of the nozzle.

At the start of the moulding cycle the nozzle or valve member 26 is held forward under pressure by the piston and cylinder 29, 27 thereby closing the valve port 42. The screw ram 18 contains molten resin and the slide valve 21 is open. The chamber 35 is also filled with the measured quantity of pressurised gas, and the valves 36 and 39 are both closed.

Operation of the screw ram 18 introduces the molten resin into the mould cavity 13 through the opening 43 via the hot runner manifold 17 until the cavity is filled. The slide valve 21 is then closed and the screw ram refilled with molten resin. The valve 36 is then opened and the piston and cylinder 33, 34 is operated to introduce gas through the nozzle 26 into the molten resin within the mould cavity thereby creating a gas containing hollow in the plastics material. The pressurisation in the gas is maintained by the piston and cylinder 33, 34 whereby more pressurised gas is caused to enter the molten resin to take-up shrinkage in the resin ad it cools. The resin in the mould is thereby held positively against the mould surface as the resin solidifies and cools until the moulding can itself sustain the form dictated by the mould surface.

The valve 36 is closed and the piston 33 withdrawn. The cylinder 34 is then refilled with another measured quantity of gas under pressure. The valve 39 is also opened and the gas downstream of the valve 36 in the connection to the nozzle 26 passes to waste.

Furthermore, the valve 40 is reversed so that the piston 29 withdraws the nozzle 26 and the gas in the gas containing hollow passes through the opening 44, the open valve port 42, and the second passageway 51, around the nozzle 26 to the atmosphere thereby venting the gas pressure in the hollow 25 to the atmosphere. The mould 10 is then opened and the moulding removed. Finally the piston and cylinder 29 is operated to return the nozzle 26 to its forward position to await the introduction of molten resin during the next moulding cycle.

Figures 2 to 4 of the drawings show one example of an injection moulding of thermoplastics resin produced by the method of the present invention, the moulding having an unevenly distributed arrangement of rib structures 1, and boss structures 2. The moulding also has hollow sections 3 produced by injecting gas under pressure into the molten resin which has already filled the mould cavity. Both the molten resin and the pressurised gas are injected through the same gate s ction 4. The moulding has practically no visible outward bending of the surfaces corresponding to the rib structures 1 and the boss structures 2. If desired, there may be provided more than one gate 4 for injection of the gas under pressure.

Two examples are described below of the present invention being employed to produce mouldings, as well as comparative examples using conventional injection moulding. The pressures used are gauge pressures.

<u>Example 1</u>

The moulding shown in Figure 1 was produced using polycarbonate resin (manufactured by Mitsubishi Gas/Chemicals Co., Ltd. and sold under the trade name "YUPIRON S-3000") as the thermoplastic resin. The resin was melted at 300°C in the cylinder of an injection moulding unit. The plasticized polycarbonate resin was injected into the mould cavity through the gate 4 with an injection pressure of 28 kg/sq.m to fill the mould cavity. After 2 seconds pressurised nitrogen gas was injected through the same injection inlet gate 4 at 30 kg/sq.m. The mould cooled and after 45 seconds the internal pressure in the hollow sections 3 was relieved by venting the gas therein to the atmosphere. The mould was then opened and the moulding removed. The weight of the moulding was 373 g, the outward bending was 0.1mm, and the inward bending was 0.1mm. The moulding was of excellent appearance with practically no sign of inward or outward bending.

<u>Comparative Example 1</u>

For comparison purposes, mouldings were produced using the same operations described in the above Example 1, except that pressurised nitrogen gas was not injected. However, the injection pressure of the molten resin was raised to 81 kg/sq.cm and the cooling period was extended to 65 seconds. The weight of the resulting moulding was 440 g, the outward bending was 0.6 - 0.8mm, the inward bending was 1.0 -1.2mm, and the rib and boss sections exhibited clear inward bending.

Example 2

A rubber-modified polystyrene resin (manufactured by Mitsubishi Monsanto Chemical Co., Ltd. and sold under the trade name "Dialex HT-88") was used as the thermoplastic resin, and all the operating conditions were the same as the above Example 1, except that the resin temperature in the cylinder was 230°C. The weight of the moulding obtained was 232 g, the outward bending was 0.2 -0.3mm, the inward bending was 0.1 - 0.2mm, and again practically no outward or inward bending could be seen on the moulding.

Comparative Example 2

The above Example 2 was repeated except that pressurised gas was not injected, the resin injection pressure was 65 kg/cu.cm, and the cooling time was again extended to 65 seconds. The weight of the resulting moulding was 391 g, the outward bending was 0.8 - 0.9mm, the inward bending was 1.9 - 2.1mm, and both inward and outward bending were clearly visible.

As will be appreciated from the above described examples, minimal outward and inward bending is obtained in the mouldings when using the method of the present invention. Also, the hollow sections extend throughout the whole of the moulding in unevenly distributed wall sections which contain rib and boss sections.

Claims

1. A method of producing resin mouldings comprising introducing molten synthetic thermoplastic resin (19) into a mould cavity (13), introducing pressurised gas into the resin, and allowing the resin moulding to cool and harden in the mould cavity whilst maintaining the gas under pressure, the mould cavity being designed to manufacture mouldings with unevenly distributed thick walled sections connected to at least one gate (4;44) for the introduction of the pressurised gas, characterised in that the mould cavity (13) is completely filled with the resin, and subsequently the pressurised gas is introduced into the resin within the mould cavity during the cooling of the resin, the gas flowing only within the resin forming the thick walled sections (3) and immediately adjacent areas of the moulding and ther by taking up th shrinkage in the resin.

2. A method as claimed in Claim 1, characterised by maintaining the pressure of the gas within the gas filled sections (3) during the cooling stage of the moulding cycle until the moulding can itself sustain the form dictated by th mould surface.

3. A method as claimed in Claim 2, characterised by subsequently venting the gas filled sections (3) to the atmosphere before opening the mould.

4. A moulding produced by a method as claimed in any one of the preceding claims.

FIG. 1.

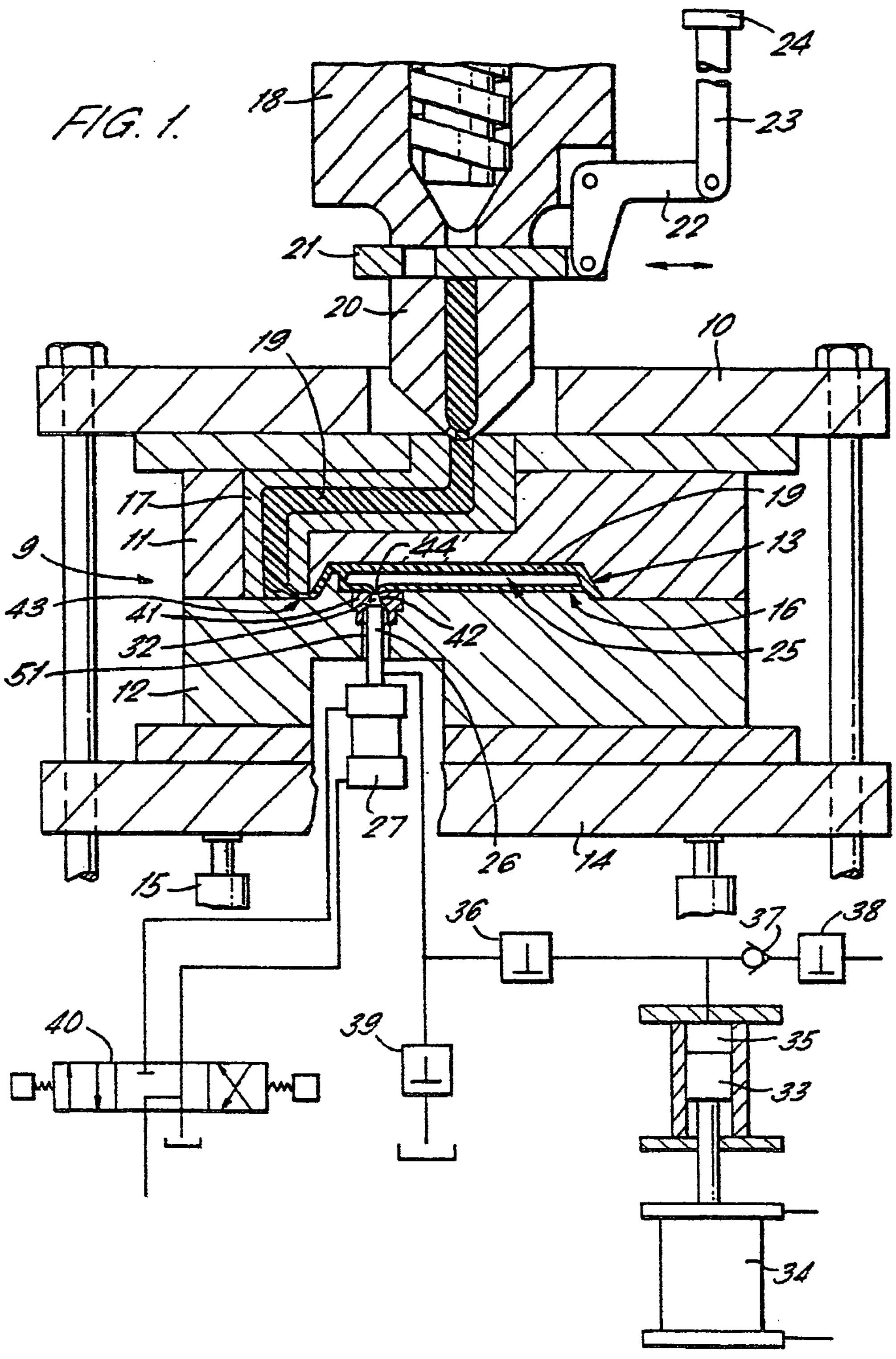
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FIG. 2.

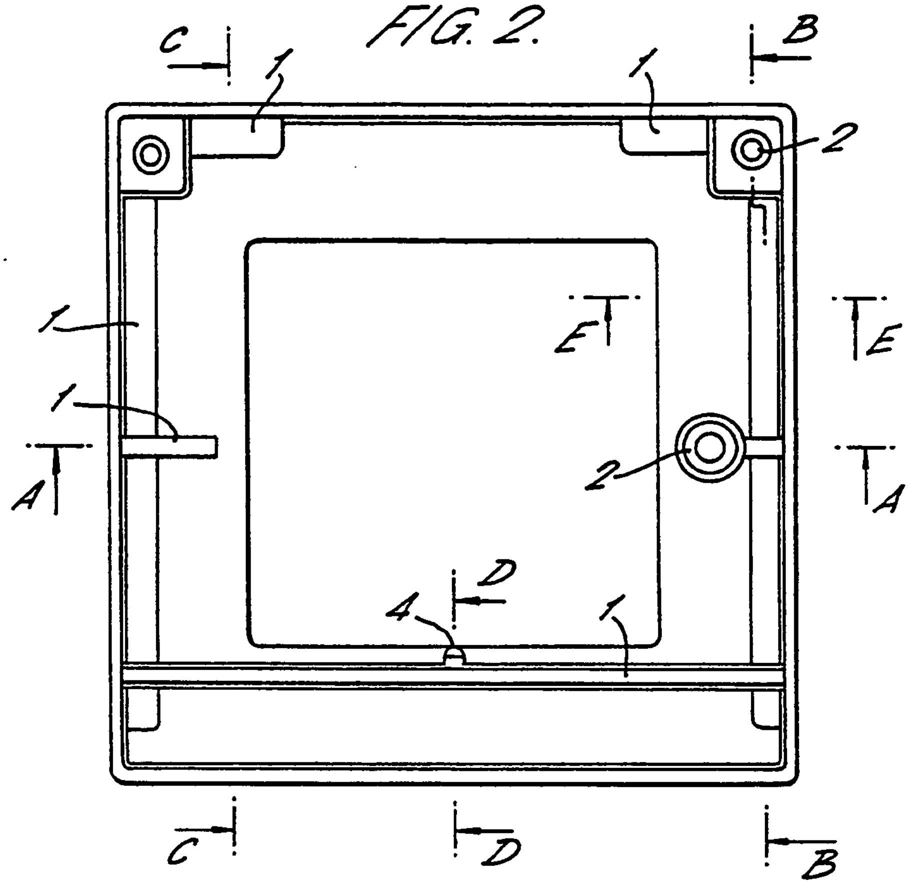


FIG. 3.

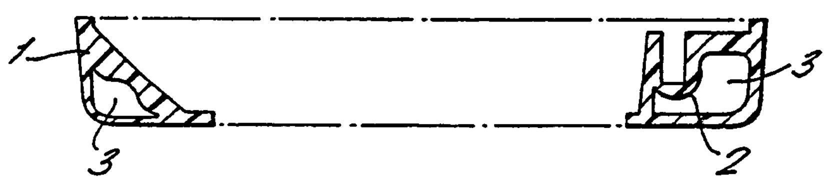
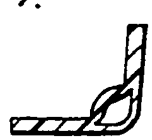


FIG. 7.



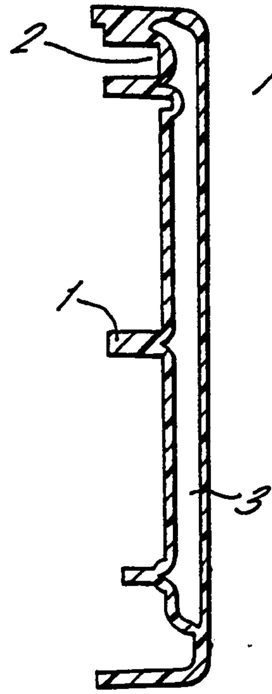


FIG. 4.

FIG. 5.

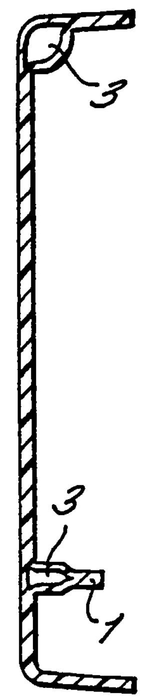


FIG. 6.